Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Operation in the TV Broadcast Bands	)	ET Docket No. 04-186
Additional Spectrum for Unlicensed Devices	)	ET Docket No. 02-380
Below 900 MHz and in the 3 GHz Band	)	

COMMENTS OF MICHAEL J. MARCUS, Sc.D.

Summary

These comments express general support for the proposals in this NPRM. Specifically issues relating to the "hidden node" problem and "feature detectors" are reviewed. The hidden node problem is the basic concern that unlicensed devices might cause interference to TV receivers because they might misjudge how much power they can use without causing interference. While solutions involving the active participation of broadcasters could avoid this problem, this creates uncertain incentives for broadcasters to cooperate with unlicensed users. Feature detectors are shown to be a likely cure to the hidden node problem. Feature detector technology was developed by the US military for certain intelligence applications and is not well known among the FCC staff and the industries regulated by FCC. However, the FCC sponsored a public presentation on this topic on Feb. 12 2003 so adequate information on the topic is in the public domain and even on the FCC's own web site!

The wireless microphone issue is also addressed. While this may not seem like a major issues, it is shown that the proposal in the NPRM is inadequate to protect these licensed systems. Alternative approaches are feasible and probably will be needed should the Commission wish to continue the present status of these wireless microphones in the UHF TV bands or the Commission might wish to review whether status of these devices is appropriate in view of technological change.

Background

These comments represent my personal thoughts on this issue and are not being presented on behalf of any third party, with or without compensation.[1] The Commission is well acquainted with my technical qualifications relating to this proceeding. I was employed at the Commission for almost 25 years, most recently as Associate Chief for Technology, Office of Engineering and Technology. This year I was recognized as a

[1] *See* 18 USC 207(j)(4)

Fellow[2] of the Institute of Electrical and Electronics Engineers for "leadership in the development of spectrum management policies." The June 12, 2004 issue of *The Economist* described me as a "visionary" for my leadership in the early 1980s in urging the Commission to adopt what are now known as the "unlicensed bands". I codirected the preparation of the Cognitive Radio NPRM, Docket 03-108, which is closely related to this proceeding.

<u>What is the "hidden node" problem?</u>

This odd piece of technical jargon is relatively new in the FCC arena, but has been used in technical literature for at least two decades. A communication network generally consists of both transmitter and receiver nodes. While transmitters are generally easy to detect directly, receivers can not be detected directly in most cases because they are passive.[3]

Figure 1 shows the basic components of the hidden node problem. On the left

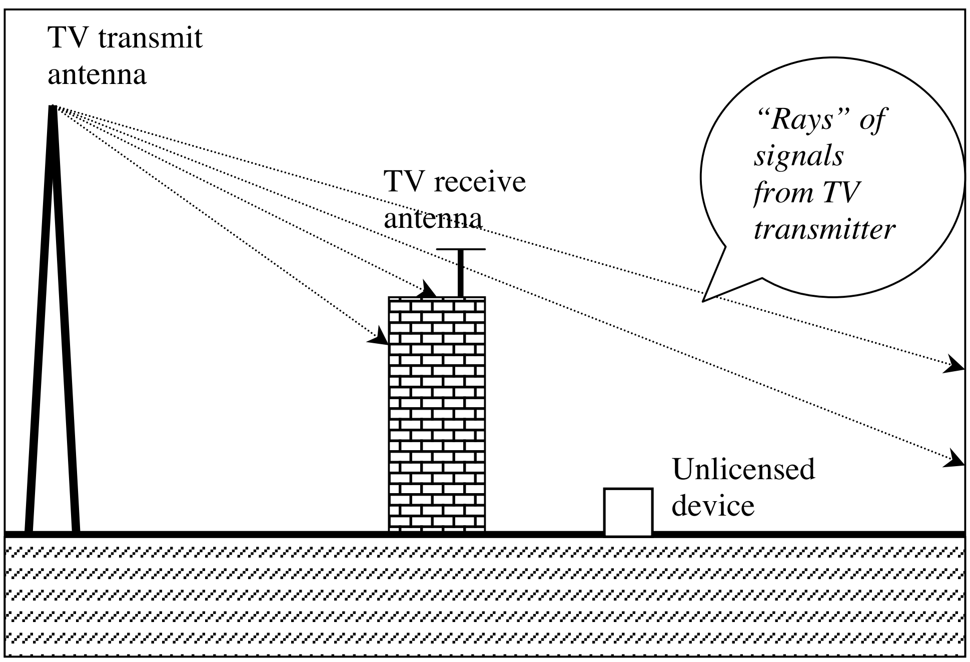

Figure 1: Components of the hidden node problem

[2] *See* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-243463A1.pdf

[3] While receivers are passive in the traditional sense, they are also considered unintentional emitters in the context of Part 15 of the Commission's Rules. Real receivers actually do emit on frequencies that are a function of what they are tuned to. These emissions have been exploited by both rating companies trying to estimate viewership and overseas government broadcasters seeking to detect receivers that have not paid receiver fees. Thus, the use of such receiver emissions has been well established.

is the broadcast TV transmitter. Its signals are shown schematically as “rays”. UHF signals do not really behave like optical rays because the wavelengths involved, roughly 1m to 60 cm, are large enough to result in some bending of the rays as they pass obstacles such as buildings. Nevertheless, rays are a convenient way to depict propagation and building shielding can result in significant decrease in received signals such as 40 dB drops over free space.

In the center of Figure 1 is a building with a TV receive antenna on top.[4] It is in line of sight of the TV transmitter and thus receives a good signal. However, the “shadow” of the building shields the location of the unlicensed device such that the unlicensed device sees no direct path to the TV transmitter and suffers from a shadowing propagation lost of up to 40 dB compared to the TV receive antenna on top of the building. The next result is shown in Figure 2 below.

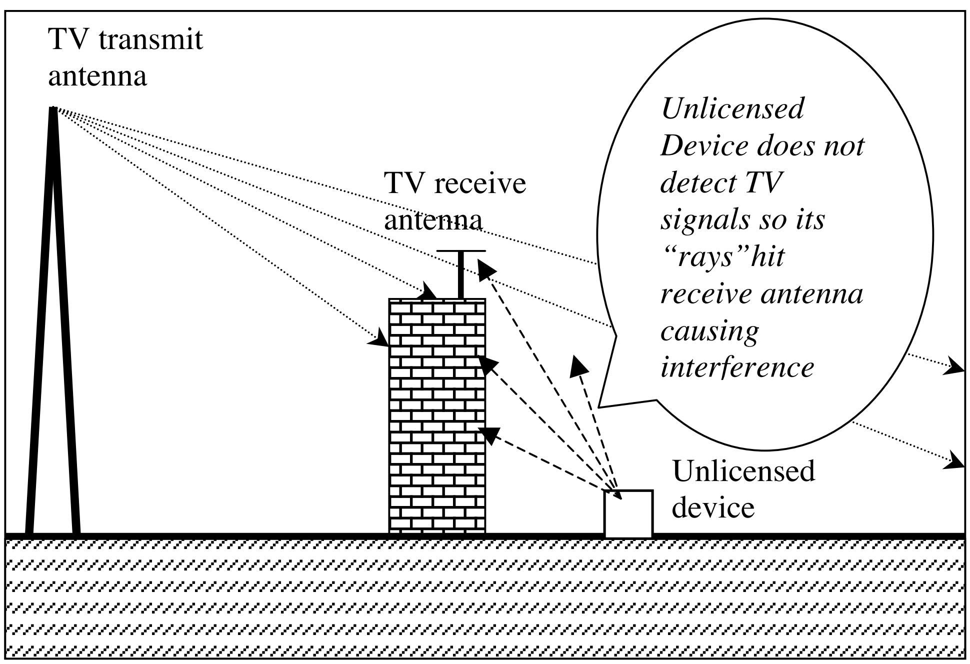

Figure 2: Interference from the hidden node problem

[4] An outside antenna such as this is the worst case scenario. Since most Americans receive signals from cable systems or satellites and a large fraction of the remaining use indoor antennas (“rabbit ears”), probably only a small number of American households use this configuration. However, I am not aware of any quantative data in this area.

Because of the building shadowing in Figure 2, the unlicensed device does not detect enough of the signal from the TV transmitter to detect its presences, falsely concludes that there is no potential for interference, and then transmits on the TV transmitter's frequency. The short direct path to the TV receive antenna results in s strong undesired signal at the TV receive antenna and interference.

Footnote 34 of the Notice recognized this problem stating,

> Spectrum sensing has a disadvantage that is sometimes referred to as the "hidden node problem." In the case of unlicensed devices in the TV band, this problem could arise when there is signal blockage between the unlicensed device and a TV station, but no blockage between the TV station and a TV receiver and no blockage between the unlicensed device and the same TV receiver. In such a case, the sensing receiver in the unlicensed device may not detect the presence of the TV signal because it is blocked, and the unlicensed device may therefore commence transmissions on an occupied channel, thus causing interference at the TV receiver.

It seems odd that the Notice focused so much on this problem but quickly passed over a point that is a likely solution. Para. 20 of the Notice observes,

> As the Commission has previously noted, there are techniques that can be used to increase the ability of a sensing receiver to reliably detect other signals in a band which rely on the fact that it is not necessary to decode the information in a signal to determine whether a signal is present.

This is slightly elaborated on in fn. 35,

> For example, sensing can be made more sensitive by using bandwidths much smaller than a 6 MHz TV channel and/or can look for specific features of the TV signal such as the visual and audio carriers. *See Notice of Proposed Rule Making and Order* in ET Docket No. 03-108, 18 FCC Rcd 26859 (2003).

This footnote fails to give a specific site to the section of the Docket 03-108 NPRM nor does it give much detail about what is meant by "techniques that can be used to increase the ability of a sensing receiver to reliably detect other signals in a band". For the benefit of the Commission and commenting parties, let me point out that the specific cite to the Docket 03-108 NPRM is para. 25 which states,

> There are techniques that can be used to increase the ability of a sensing receiver to reliably detect other signals in a band which rely on the fact that it is not necessary to decode the information in a signal to determine whether a signal is present. For example, the use of specialized detectors can improve the ability to sense the presence of other signals by 30-40 dB. Most applications of signal detection in

> commercial practice are based on "radiometric detectors" which only function if the signal is greater than the noise level in the receiver system. However, in the past decade information has become available about an alternative technology called cyclostationary detectors or feature detectors which use longer sensing times and internal computation to achieve signal sensitivities below the noise level for signals of known format. By processing a large number of transmitted symbols, without the need to demodulate them individually, such a feature detector can achieve a processing gain over a radiometric detector which does not use knowledge of the signal format. In practice, processing gains of 30-40 dB can be achieved with computation resources typical of today's microprocessors. With such a detector capable of receiving signals more than 30 dB below the noise floor the hidden node problem (Citations deleted)

Footnote 34 of the Docket 03-108 NPRM adds,

> The Commission has held tutorials discussing the use of feature detectors and commenters have described the application of these techniques to various spectrum sharing scenarios. *See* John W. Betz, PhD, Feature Detection, (Feb. 12 2003), *available at* http://www.fcc.gov/realaudio/presentations/2003/021203/featuredetection.pdf; *see also* Shared Spectrum Company, Hidden Node Problem Discussions, *ex parte* (Sep. 25, 2003), *available at* http://fccweb01w/prod/ecfs/retrieve.cgi?native-or-pdf=pdf&id-document=6515182975. Dr. Betz's presentation contains a detailed bibliography of academic publications on the subject.

I urge the Commission and commenting parties to review Dr. Betz's presentation at the FCC. Unfortunately, the video of the presentation is no longer available online at the Commission website, but perhaps this can be changed. In any case, interested parties can order a copy of the video from the Commission's contractor at a modest cost.[5] The slides of Dr. Betz's presentation are still available online at http://www.fcc.gov/realaudio/presentations/2003/021203/featuredetection.pdf and gives a detailed discussion of feature detectors[6] as a way to counter the hidden node problem. The video presentation has mode details on the bottom line effectiveness of this technology.

Feature detector technology is a novel issue for both the FCC staff and most parties commenting in this proceeding. The technology was developed during the Cold War for very sensitive programs dealing with detection of foreign communications signals that sought covertness. Specifics of how it has been used and operational equipment are not in the public domain. However, the shield of secrecy has fallen from this technology. Dr. Betz works for a major military contractor and had clear and explicit

[5] *See* http://www.fcc.gov/realaudio/ for ordering details

[6] Also called cyclostationary detectors

permission from the Department of Defense to give his public presentation at FCC. Further more he listed 14 open literature publications which deal with this technology and which could be useful to the Commission and commenting parties. As a public service, I am listing these in the Appendix to these comments. Adequate information about this technology is now in the public domain for the Commission to consider its commercial use.

Footnote 35 of the Notice in this proceeding stated that "sensing can be made more sensitive by using bandwidths much smaller than a 6 MHz TV channel ". While this is true for NTSC signals which have very uneven power spectral densities, it is not very useful for DTV signals which have only nominal variations in power spectral density. However, the feature detector technology can be used for both NTSC and DTV signals.

A normal receiver detects a signal by demodulating the information it carries. This requires a signal greater than the noise that is present. For NTSC the signal must be at least 20 dB greater than the noise (a factor of 100), while for DTV about 10 dB (a factor of 10) is needed. A radiometer detector is the typical receiver used in radioastronomy and for applications involving signal detection without demodulation. It still requires the signal to be greater than the noise that is present. However, a feature detector receiver knows specifically what format signal it is looking for and only has to answer the question "Is this signal present?". It can take as generous amount of time to make this decision. By contrast, a DTV receiver must make almost 20,000,000 decisions a second about whether a zero or a one was sent. The feature detector uses this increased time availability to increase its sensitivity compared to a normal receiver. Simple theory shows the gain in sensitivity increases with decision time and can be infinite, but practical considerations limit achievable gain since radio propagation affects the signal and clocks are not perfectly accurate. In his presentation, Dr. Betz indicates that gains of over 40 dB (a factor of 10,0000) are possible using processing power comparable to today's household personal computers in the case of NTSC and DTV signal detection.

Does 40 dB sound familiar? Isn't that the number I mentioned previously as the shadowing loss in Figures 1 and 2? The feature detector could be used to overcome this shadowing loss and prevent the hidden node problem. The necessary computations could bee done either in the unlicensed device or in the computer to which it is attached. The computations may have to be repeated on a regular basis, but once every few minute would probably suffice and would not be a significant burden for today's personal computers.

Regardless of what other approaches the Commission considers for unlicensed use of UHF TV bands, I urge it to permit permissive use of feature detector technology to allow unlicensed systems to find frequencies that can be used without harmful interference.

Other commenting parties who are interested in the capabilities and limitations of this technology should feel free to contact me for information in this area.

Wireless Microphone Issue

Para. 38 discusses the issue of wireless microphones who operate under Part 74 in the UHF-TV bands which are being considered. While their operation resembles an unlicensed operation in many ways, the limited user eligibility and the Part 74 location of the rules results in them having the status of licensed operations vis-à-vis the unlicensed operations proposed in the notice. Thus interference to such wireless microphones is a serious concern for the outcome of this rulemaking.

Specifically, para. 38 states,

> We believe that the operational characteristics of wireless microphones significantly reduce the likelihood of interference from unlicensed devices for several reasons. Wireless microphones are permitted relatively high output power given the range over which they are typically operate. The maximum permitted output power of these devices is 50 milliwatts in the VHF band and 250 milliwatts in the UHF band.60 Wireless microphones are used in locations such as theaters and sports arenas where the operating range would typically be hundreds of feet at the most, so operation at the power levels permitted in the rules results in a significant signal level at the wireless microphone receiver. Further, the vast majority of wireless microphones are frequency modulated (FM). FM receivers exhibit a "capture effect" in which they respond to only the strongest signal received on a frequency and reject any weaker interfering signals. <u>Because the desired signal at a wireless microphone receiver is relatively strong, we believe that the likelihood of interference from unlicensed device signals is therefore low such that unlicensed use should generally be compatible with wireless microphones.</u> (Emphasis added.)

I strongly disagree with the conclusion underlines in the above quote. What matters for interference to occur is the desired-to-undesired ratio at the receiver which is an function of <u>both</u> the powers <u>and</u> distances involved. This is the classis near/far problem. If an unlicensed device is close to the receiver if could well overpower the desired signal. Just imagine a theater patron using a PDA equipment with an unlicensed device such as proposed in this notice. Who unknowingly is seated near the wireless microphone receiver in the theater. Interference is very likely.

The basic problem here is that broadcasters and certain other entertainment-related industries have been given preferential treatment compared to all other possible users in access to UHF-TV spectrum on what is *de facto* an unlicensed basis for wireless microphones and even short range video. The original basis for this policy in ancient history was that such use of UHF spectrum was risky with respect to interference and only broadcasters were responsible enough to take the correct precautions. Of course, later nonbroadcasters were added to the eligibility. Why a Hollywood-based movie production company has special knowledge about TV spectrum in Iowa that allows it to use the spectrum but forbids most Iowa residents to use the spectrum has always puzzled me. However, with today's technology the responsibility can be shifted to technology which can search for idle spectrum with no interference potential. Thus both Iowa residents, Iowa broadcasters, and even transient Hollywood production companies could all use the same spectrum if they were on a equal footing.

In summary, the wishful thinking of para. 38 fails to prevent interference in this case. The Commission has several alternatives: 1) dismiss the proposals in this Notice, 2) permits wireless microphones and similar Part 74 devices on only some of the channels and allow unlicensed devices on the others, 3) remove the preferential treatment that the Part 74 devices have had as *de facto* unlicensed devices by moving them to Part 15, or 4) requiring the Part 74 devices to use similar mechanisms as the proposed Part 15 devices, perhaps under preferential terms, to allow as many users as possible to use the spectrum resource on a noninterferring basis. I urge option 4. If the technology being considered is cheap enough for consumer devices, broadcasters can find room in their budgets for it.

Conclusions

I urge the Commission to include permissive use of feature detection technology as at least an alternative way for unlicensed devices to access UHF-TV spectrum on an unlicensed basis. I have no objection to the other alternatives in the Notice. Feature detector technology is capable of autonomously solving the "hidden node problem" on a reliable basis. If the broadcast industry can not accept this, I suggest adopting rules which are conditional on a field trial which will show the reality of the situation.

The wireless microphone situation is more difficult than the Notice admits. Strict interpretation of present rules and policies relating to wireless microphones and similar devices will preclude unlicensed use of this spectrum. The root cause of the problem is the preferential access given to the few groups who are allowed to uses wireless microphones and similar technologies. Equalizing spectrum access, or bringing it at least to a somewhat more egalitarian basis, is in the public interest and would allow both present and new users access to the spectrum.

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APPENDIX

Bibliography of Open Literature Articles on Feature/Cyclostationary Detectors

Source: http://www.fcc.gov/realaudio/presentations/2003/021203/featuredetection.pdf

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